Pomeron in Elastic Scattering

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ABSTRACT

Pomeron has been an object of intense study these days in elastic and deep inelastic scattering. We still do not know where it is a soft or hard Pomeron. In our study we analyze the Pomeron in elastic scattering taking the entire data into consideration.

Strong interactions continue to be a challenge in theoretical high energy physics. Problem is even more difficult to handle in the non-perturbative or soft region [1]. Some attempts have been made to study the same in the purturbative region using QCD [2]. In order to have a deeper understanding of this problem pomeron is being employed within the framework of Regge theory and to relate it to QCD. The pomeron is related, in a hadronic scattering process, to the rightmost singularity of the partial scattering amplitude in the complex angular momentum plane. The scattering amplitude is associated to the presence of an exchanged object with vacuum quantum numbers, which leads to a power law, increase of the total cross section with centre of mass energy.

Experimental Measurements for Elastic Scattering

Current status of the measurements of various parameters for elastic scattering is as follows: The total and differential cross section, σ_T and $d\sigma/dt$, elastic cross section, σ_{el}; the local slope parameter, B and ratio of the real and imaginary parts of the scattering amplitude, ρ have been measured by several authors [3-24] at CERN-ISR, CERN-SPS, and FERMILAB. Experiments currently active in $\bar{p}p$ elastic scattering are - CDF, E710 [25] and E811 at FERMILAB. Measurements from the Cosmic ray data corresponding to LHC energy [26] have also been reported recently for *pp* elastic scattering. There is general consistency of the experimental data measured at different colliders except the CDF results at FERMILAB. Their results are $\sigma_T = 80.03 \pm 2.24$ mb, B = 16.98 ± 0.25 $(GeV/c)^2$, $\sigma_{el} = 19.70 \pm 0.85$ mb at $\sqrt{s}$ = 1.8 TeV. This is significantly different from E710 results of $\sigma_T = 72.2 \pm 2.7$ mb, B = 16.99 ± 0.47 $(GeV/c)^2$, $\sigma_{el} = 16.6 \pm 1.6$ mb. Recently E-811 collaboration has measured $\bar{p}p$ elastic scattering in the small momentum region. The data is being analysed currently and results at 1.8 TeV are expected shortly. These results will be of quite significance in the light of discrepancy of CDF and E710 data.

Pomeron in S-Matrix theory

The pomeron was first introduced in the early sixties in the framework of the complex angular-momentum theory, to describe high-energy soft processes. After expanding the scattering amplitude in partial waves, it is assumed that the partial wave amplitude a(j,t) is dominated by an isolated, simple, moving pole located in the complex angular-momentum plane j at some value $\alpha(t)$,

$$a(j,t) = \beta(j) / ((j - \alpha(t)),$$

using a well-defined mathematical prescription known as the Sommerfeld-Watson transform, it is found that the asymptotic behaviour of the elastic-scattering amplitude A(s,t) in the limit $s \gg m^2$, $t \approx 0$, $s \rightarrow \infty$ is given by

$$A(s,t) = \xi(\alpha)\, \beta(\alpha)\, (s/s_0)^{\alpha},$$

where ξ (α), known as signature factor, can be written as

$$\xi(\alpha) = \{1 + \xi \exp(i\pi\alpha)\} / \sin \pi\alpha , \qquad \xi = \pm 1 .$$

In the above equation, β (t) is known as the residue function, $\alpha \equiv \alpha$ (t) is called Regge trajectory and s_0 is a scale parameter.

A single pole exchange (i.e. a simple moving pole in the complex angular momentum plane) is the simplest ingredient normally used as a basic part of the dynamics and it leads to predict a power behaviour of the scattering amplitudes, More realistic models may involve more complicated j-plane structures, either generated by unitarity (Regge cuts) and/or coming from a more involved input (like a double pole) [27]. Perturbative QCD calculations indicate that the pomeron may be a complicated j-plane structure. Phenomenology of hadronic reactions, on the other hand, also points independently, towards a complicated j-plane structure whereby integrated hadronic cross-sections grow as *Ins* or $In^2 s$ (a kind of growth traditionally attributed to cuts in the complex angular-momentum plane).

.There are many confusing ideas about the pomeron . One of the most persistent is that there are two pomerons - a soft and hard. Soft (used to explain diffraction phenomena) and hard (used to explain small x phenomena in DIS and calculated from perturbative quantum chromodynamics, pQCD). There are different competing approaches for the explanation of soft and hard Pomeron. More specifically, Pomeron can be visualized as a complicated entity which in different dynamical situations may have different manifestations but whose origin is always the same, diffraction. The twofold interpretation of single object or phenomenon. It however has a clear origin: the conventional pomeron studied in hadronic physics is a soft phenomenon, out side the range of applicability of perturbative quantum chromodynamics. What has come to be known, as the hard pomeron is something that can be calculated from perturbative quantum charomodynamics.. It is likely that there is only one object and the diversity of its manifestations reflects merely the diversity of the reactions in which it can occur and of the physical and kinematics situations in which it is investigated. More specifically, we visualize the pomeron as a very complicated entity, which will, in fact, be a function of different sets of variables depending on the reaction one is looking at. In different dynamical situations it may have different manifestations with the same origin. In our paper we will take up the role of Pomeron in elastic scattering. The recent small-x data collected at HERA were interpreted by some authors as a manifestation of the hard pomeron, and thus as an argument in favour of the existence of two pomerons [28]. However, much better data, more conclusive analyses and even better understanding will perhaps help us in having a clearer picture of the Pomeron in the near future

We now know that elastic and total cross section data which poses much problem for the physicists specially in the diffractive region is well described by Regge theory. In addition to Pomeron, Regge trajectories A_2, ρ, ω, ... are exchanged at lower energies ($10< \sqrt{s} < 53$ GeV) [29]. However, as the energy increases only the pomeron with an intercept ≈ 1.07 can account for the total cross section data up to Tev energies. In literature there are various values for the soft pomeron which lye in the range of 1.07 ± 0.02. This is mainly dependent on the choice of range of experimental data and error bins at very high energies. It is also true for the differential cross section in the diffractive region. For the large momentum transfers Pomeron alone is not sufficient and contribution of other trajectories or Odderon (specially in the vicinity of dip region) is desired. At the same time it appears that contribution of the cuts is also essential.

The focus will also be on the recent progress made in understanding of the role of soft interactions in the hard processes, in particular in deep inelastic lepton scattering. This will include the new data on low-x deep inelastic scattering and diffraction from the experiments H1 and ZEUS at HERA with particular emphasis on theoretical developments and perspectives. We will also take in to account the expected results with higher luminosity measurements expected from HERA, Run II at Fermilab Tevatron collider, COMPASS, polarized RHIC and LHC in years 2000 and beyond. In general the process is deeply related to non-perturbative phenomena and the only possibility to understand as much as possible of it is to consider processes involving the scattering of highly virtual photons or onia-particles.

REFERENCES

1. P.V. Landshoff DAMTP 96/48 (1996).
2. A.H Muller, Nucl Phys. **B415** 373 (1994); B437 107 (1995)..
3. M. Holder et al., Phys. Lett. **B 35**, 355 (1971); **B 36**, 400 (1971).
4. G. B. Yodh et al., Phys. Rev. Lett. **28**, 1005 (1972).
5. G. Barbiellini et al., Phys. Lett. **B 39**, 663 (1972).
6. U. Amaldi et al., Phys. Lett. **B 36**, 504 (1971); **B 43**, 231 (1973).
7. A. Bohm et al., Phys. Lett. **B 49**, 491 (1974).
8. N. Kwak et al., Phys. Lett. **B 58**, 233 (1975).
9. H. De Kerret et al., Phys. Lett. **B 63**, 477 and 483 (1976); Phys. Lett. **B 68**, 374 (1977); **B 69**, 373 (1977).
10. J. H. Snyder et al., Phys. Rev. Lett. **41**, 781 (1978).
11. E. Nagy et al., Nucl. Phys. **B 150**, 221 (1979).
12. S. J. Brodsky and G. P. Lepage Phys. Rev. **D24**, 1808 (1981).
13. R. Battiston et al., Phys. Lett. **B 115**, 333 (1982). Phys. Lett. **B 127**, 472 (1983).
14. N. Isgur and C.H.Llewellyn Smith, Phys. Rev. Lett. **52**, 1080 (1984).
15. S. Erhan et al., CERN-EP/84-147 (1984).
16. A. Breakstone et al., Nucl. Phys. **B248**, 253 (1984); Phys. Rev. Lett. **54**, 2180 (1985).
17. M. Bozzo et al., Phys. Lett. **B 147**, 385 (1984). Phys. Lett. **B 155**, 197 (1985).
18. S.J. Brodsky and C.Ji, Phys. Rev. Lett. **55**, 2257 (1985).
19. D. Bernard et al., Phys. Letts **B 186**, 227 (1987); **B 189**, 583 (1987); **B 171**, 142, (1986).
20. G. Augier et al., Phys. Lett. **B 316,** 448 (1993); CERN/ PPE 94-160 (1994).
21. N.A. Amos et al., Phys. Rev. Lett. **68** 2433 (1992); and “Aspen 1993, Multiparticle dynamics” 395- 399 In “Providence 1993, Elastic and diffractive scattering” 59-6.
22. F. Abe et al., Phys.Rev. **D50**, 5518 (1994).
23. M. Honda et al., Phys. Rev. Letts. **70**, 525 (1993)
24. S.M. Pruss, Proceedings of 6th Blois Workshop “Frontiers in Strong Interactions”, Blois, France, 3 (1995) (Editions Frontieres).
25. N. Amos *et al*., E710 Collaboration., Phys. Rev. Lett. **61**, 525 (1988).
26. S. Torii, Proceedings of 6th Blois Workshop “Frontiers in Strong Interactions”, Blois, France, 9 (1995) (Editions Frontieres).
27. E. Levin, hep-ph/9503399.
28. P.Desgrolard, M.Giffon, A.Lengyel and E.Martinov, N.C. Vol. **A 107** 637 (1994).
29. R. J. M. Covolan, P. Desgrolard, M. Giffon, L. L. Jenkovszky, and E. Predazzi, Z. *Phys*. **C58,** 109 (1993).